

FOR THE DESIGN, CONSTRUCTION AND ENJOYMENT OF UNUSUAL SOUND SOURCES

# EXPERIMENTAL MUSICAL INSTRUMENTS

## ALWAYS SOMETHING

The photograph below shows the Till Family Rock Band. The band members are posing with a lithophone, probably made in the 1870s using stones found in the Lake District of northwestern England. The Till instrument and other 19th century English lithophones are described in the article by Dr. A.M. Till, a descendent of the original family, in this issue of **Experimental Musical Instruments**. Also in this issue we have David Courtney's description of the varieties of string instrument bridges in India, a report on the offbeat electronics of Reed Ghazala, the first half of a two-part article on wind instrument air column acoustics, an archaic home-built electronic organ, plus the usual mix of letters, reviews and additional odds and ends.

Welcome. Read.

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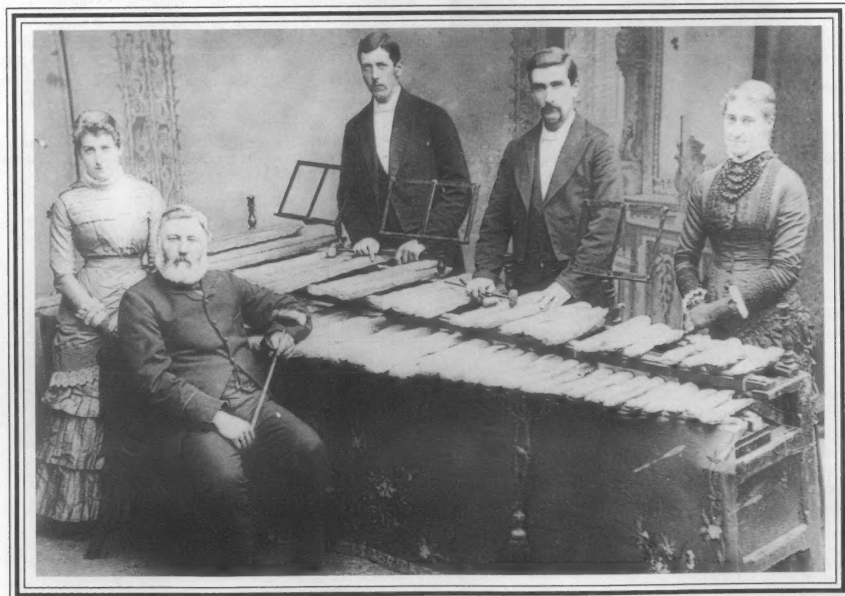


Photo above: The Till Family Rock Band. See the article starting on page 12.

THE POLAROID PHOTO [reproduced below] is of a "Rain Chime" being sold by the San Francisco Bay Area *Nature Company*. I was so impressed, I purchased one and gave it to my parents for their 40th anniversary. Basically, it has four tuned chimes suspended and enclosed in the box. On the ceiling of the box is a sheet of adhesive (apparently of a type similar to the 3M Post-It note sheets). Sealed in the box are hundreds of small steel ball bearings. Shaking the box while upside-down lodges the balls on the adhesive. Righting the box starts a slow rainfall, as the balls dislodge and hit the chimes, often bouncing to other chimes before resting on the floor of the box. The balls fall at random, giving about a 5-10 minute concert. Very enjoyable. The manufacturer is AG Industries, Inc., Redmond, WA 98052. There's a copyright mark also, in the name of Ken Bakeman.

Jeff Kassel

RAIN CHIME  
from  
AG Industries.



I SAW A VIDEO of Monty Python's *And Now For Something Completely Different* feature film last week. To add to the discussion of cat organs in an oblique way, there's a skit in the film where a night-club performer brings on stage a "mouse organ" (pun intended). He explains the system to the audience (caged creatures tuned in sequence as per the cat organ) and then proceeds to play "Three Blind Mice" with two large sledge hammers, striking them down upon the hapless beasts. Trouble is, the sound is a triple layer of the performer singing (or grunting) the song, the crashing of the hammers, and the *single pitch* squeaks of the mice. Considering the skit, the sound engineers/editors could have at least squeaked the song properly, considering how easy it is for a human voice to do a squeak. The hammers win out. (The audience, outraged by the cruelty, chases the performer out of the club into the street, and through several later skits.)

Ernie Althoff

IVOR WROTE A MAGNIFICENT, intelligent, generous article ["The Piano Reincarnation Project", by Ivor Darreg, in *EMI Vol. VII #3*]. What can we do with old pianos? In my book, at the beginning of the 60s, I explain my endeavors to reuse old pianos.

When my friend, Jacques Kaplan, the New York No. 1 avant-garde furrier, launched the first campaign to save wild animals in the late 60s, we planned to save old pianos, to have them stripped down, keeping only the vertical harp. These harps (sounding board and strings) should have been given to schools, so children would have been exposed to beautiful sounds for little money. The strings should have been tuned one tone lower, to avoid accidents in case of breaking.

Moreover these harps make wonderful echo chambers and I am surprised to see so few in sound artists workshops. Sound sculptures can be done using both the sounding board as amplifier and the strings to contribute an echo [see the drawing below of the Baschet Percussion Piano].

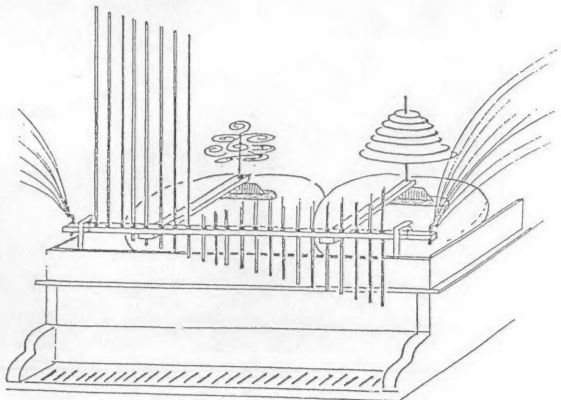
The campaign to save pianos did not work out. Journalists were interested in animals. Not in pianos. So I dropped the idea at that time.

Regarding instruments with labial reeds [discussed in "Membrane Reeds," *EMI Vol. VII #3*]: Is there any sense making a parallel with the Pathé Brothers' loudspeaker?

The Pathé Brothers had the biggest movie theater in Paris in the early 1900s. The solenoid of their speaker operated a grill, similar to an electric razor. Compressed air was released through the grill. The opening and closing of the gate (grill) was monitored by the solenoid connected to the amplifier and to the mic. In front of the grill was a big flare.

I heard the machine, which is kept at the Conservatoire des Arts et Metiers in Paris, the oldest Science Museum, started in 1792. The sound is sort of metallic, but very strong.

PERCUSSION ON PIANO, made by the Bernard and Francois Baschet around 1960. Reproduced from the unpublished manuscript. **Sound Sculpture: The Baschet Experience — Shapes, Sounds and People — 1945-1965.**

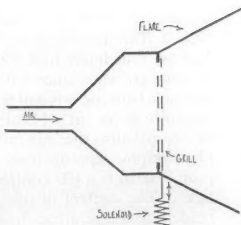


Surprisingly, the US Patent Office granted a patent on the same system around 1940, for a loudspeaker that was used by the US army in the Pacific, to insult Japanese soldiers and their mothers from planes.

Regarding Tromba Marina [discussed in Hal Rammel's "Devil's Fiddle" article, page 14, EMI Vol. VII #3]: Some authors say that "marina" does not come from the sea, but from the Virgin Mary. The T. Marina was played by nuns to replace the trumpet. The sound has some similarity and the T. Marina gives the harmonics like the trumpet.

Regarding the Aerophor [article in EMI Vol. VII #4]: In 1960 or '61, we taped an LP in Hollywood for CBS with conductor Leo Arnaud (the LP was never released) and in the studio we met a musician who was using a bellow connected, through a plastic tube, to a Y-shaped metal tube. He would put the two branches of the Y in his mouth and his instrument in between. By pressing the bellow he could sustain long sounds. He confessed that the system was not too efficient but it was an effective enough gimmick to be hired in orchestras as he was the only one using this weird system.

*Baschetus Musicalis*  
François Baschet

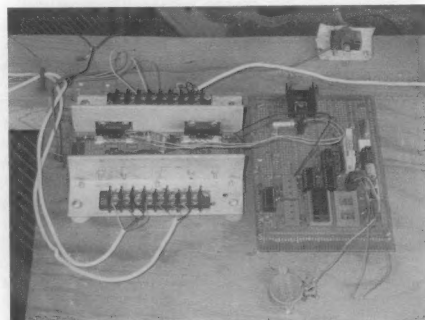


I'VE BEEN WORKING on restoring the piandemonium [a one-of-a-kind piano-based electro-mechanical instrument] at the Avant-Garde Museum of Temporary Art in Madison. The instrument has been sitting on the front porch lately and the elements have not been kind to it. Once some missing parts rematerialize the instrument will be fully functional. I have already taken photographs of it as it is presently.

I went record shopping when I was in Chicago last month — I scored a HUGE amount of stuff, including an Elpee of two ten-song "performances" by 1920s nickelodeons. They are *very cool* instruments — they sound a fair bit like the one on the latest EMI tape (the segment of "Darktown Strutter's Ball" but *more* diverse in sound (i.e. more instruments stuffed inside). COOL!

I have recently rebuilt the Rube Goldberg Record Player and I have added a wind-up motor to it, plus a speed changer. It's great — I can chipmunk 78s with it!! It does *incredible* things to 33 rpm disks.

I was pleased to see a response from Alistair Riddell to comments I made about solenoid noise in the piandemonium [Letters, EMI Vol. VII #2 and 3]. Yes, I guess in his set-up the amount of spurious mechanical noise



Below: Colin Hinz's Piandemonium. Note the battery which can power the unit when it is mobile.

Right: Piandemonium electronics (most of them, anyway), installed.

EXPERIMENTAL MUSICAL INSTRUMENTS  
Newsletter for the Design, Construction  
and Enjoyment of Unusual Sound Sources

ISSN 0883-0754

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Published in January, March, May, July,  
September and November by Experimental Musical  
Instruments, P.O. Box 784, Nicasio, CA 94948  
(415) 662-2182.

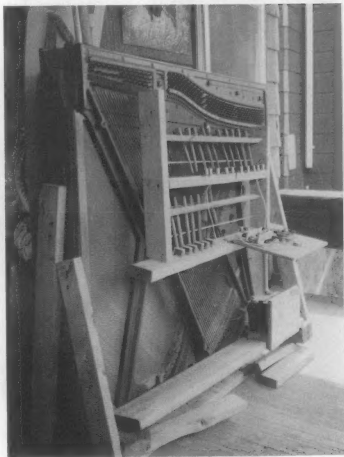
Subscriptions \$20/year (\$27 outside the U.S.,  
Mexico and Canada). Back issues \$3.50 apiece;  
cassette tapes \$6 apiece.

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would be much less than what i experience. After all, he's bypassed the hammer mechanism entirely by using push-type solenoids. I used pull-type solenoids, along with the hammer arrangement, because i built the piandemonium on the cheap and the whole mechanism is by necessity a whole lot sloppier than Riddell's. While repairing the instrument last August i managed to trace the major source of the noise i reported earlier: the inevitable misalignment between the hammer and solenoid core during the length of travel causes the solenoid core to rub against the coil body. More noticeable is the clunk made by the core striking the

back of the coil housing. Since i was loath to completely rebuild the instrument i greatly minimized the noise levels by lubricating the cores and carefully aligning the coils. Presently, the mechanical noise is enough to add needed ambience but not enough to be aggravating.

Well, if i'm working on an instrument called a pian-demonium which uses a recycled piano harp in it, it's natural that i support Ivor Darreg's Piano Reincarnation Project. I would like to get my hands on more decrepit ex-pianos but there are none to be found in this neighborhood, strangely enough.

Colin Hinz



## NOTES FROM HERE AND THERE

THE SUMPTER VALLEY JEW'S HARP FESTIVAL will take place at Sumpter Oregon, July 31 - August 2, 1992. Festival organizer Gordon Frazier writes —

The first-ever (that anyone knows of) International Jew's Harp Congress was held in 1984 in Iowa City, Iowa. (I missed it.) The second was held in the summer of 1991 in Yakutsk, in eastern Siberia. Seven Americans attended, myself included. It was pretty incredible, but that's another story.

After I got home I began meeting other Jew's harpists, and we decided to have our own get-together. It will be held July 31 to August 2 1992, at the fairgrounds in Sumpter, Oregon. Much of the time will be spent talking and, especially, playing music together. In addition, several presentations are planned. These include a Jew's Harp maker explaining his technique; a report on last year's festival in Yakutsk; the sharing of Jew's harp recordings from all over the world; and displays of Jew's harp collections.

Sumpter is in the northeastern part of Oregon, west of Baker City. RV camping is available at the fairgrounds. There is no fee for the festival itself, and the public is welcome to attend.

For more information contact Gordon Frazier, PO Box 14466, Seattle, WA 98114, phone 206/725-2718.

INSTRUMENTS OF SOUND, an exhibit of sound-producing art objects is showing at the Irvine Fine Arts Center through April 22.

The participating artists are Kai Bob Cheng, John Doe Co., Richard Dunlap, Arthur Frick, Wolf Gowin, Marlin Halverson, Catherine MacLean, Charlie Nothing, Brian Ransom, Susan Rawcliffe, Richard Waters, Daniel Wheeler, and Karen Frimkess Wolff.

Irvine Fine Arts Center is at Heritage Park, 14321 Yale Avenue, Irvine, California, 92714. For information call 714/552-1018.

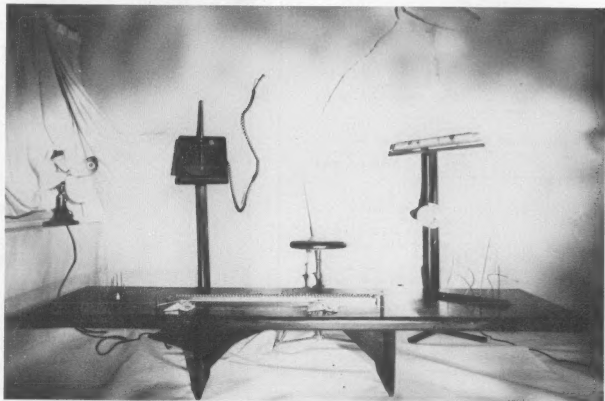
Right: Richard Dunlap's Idiophonetic Table, 1992, showing at the Instruments of Sound Exhibit, Irvine Fine Arts Center.

THE FIRST ISSUE of the **Leonardo Music Journal** has appeared. The new magazine is an offshoot from **Leonardo**, Journal of the International Society for the Arts, Sciences and Technology, which since 1967 has been at the front lines of the interface between arts and technology. The Music Journal is similar to its parent publication in editorial style and presentation, including the high quality of the paper, bindings, and photographic reproductions. Included with each issue of the print journal is a CD containing music discussed in the articles. The content of this first issue bodes well for EMI readers, with several excellent articles touching on new instruments and related topics. For a rundown on some of them, see "Recent Articles in Other Periodicals" on the back page of this issue of EMI. For subscriptions to **Leonardo Music Journal** write Pergamon Press, 395 Sawmill River Road, Elmsford, NY 110523, USA. Editorial offices are at Box 75, 1442 A Walnut St., Berkeley, CA 94709.

THE 6th BIENNIAL SOUND SYMPOSIUM takes place at St. John's, Newfoundland, July 1 - 11, 1992. Sound Symposium is an International Celebration of Sound, and a catalyst for the generation of new art in Canada. Every two years the symposium draws together hundreds of guest and local artists who explore the relationships of sound to their art forms in Newfoundland's unique environment and culture. Instrument builders and sound sculptors invited to the 1992 Symposium include Paul Lukeman, Nobuo Kubota, Gordon Monahan, Laura Kikauka, Don Wherry, Georges Azzoria, Gayle Young, Reinhard, Reitzenstein (Canada); Trimpin (Germany, U.S.), Barry Schwartz, Patrick Zentz (U.S.), ZGA (Latvia) and Hugh Davies (U.K.). For further information on Newfoundland's 6th Sound Symposium, write 81 Circular Road., St. John's, Newfoundland, Canada, A1C 2Z5, or fax 709/753-4630.

## MELODY CHUPS!

Now you can play your flute and eat it too. Something called *Melody Chups*, an actually playable candy slide whistle, has been turning up in mini-marts and convenience stores lately. The cylindrical body of the whistle is a piece of hard





The MELODY CHUPS candy wrapper, including candy slide whistle tablature for French folk songs on the back.

sugar candy (sugar, corn syrup, citric acid, natural flavor, annatto extract) of about 3/4" in diameter and 2 1/2" long. The center is hollow, forming a very narrow tube. The sounding length is extended to about 31/2" by a small embedded plastic tube. The fipple and edge arrangement is formed entirely of candy. There's a plastic stopper that slides in the tube, with small raised sections on it -- ten of them -- that form tactile stopping places for the player during sliding (not a bad idea). The raised sections are imprinted with numbers, 1 - 10, and they're spaced to yield a fairly accurate chromatic scale. The range is about an octave (including a little slidability beyond the ten marked stopping points). Printed on the candy wrapper are the melodies for "Frere Jacques" and "Sur le Pont d'Avignon" written in standard music notation and in numbers coded to the stop markers on the candy whistle's slide.

REPRODUCED AT RIGHT is a page (much reduced in size) from *Reading Rumba*, by Philip Pasmannick. *Reading Rumba* is a teacher's guide for integrating music into bilingual classrooms. It uses a traditional Afro-Caribbean percussion ensemble to perform the folkloric rhythms that inform the salsa music of today. With rhythm sheets, rhythm tracks on the accompanying cassette, and student-made drums, students can learn to perform basic beats while exploring math, physical education, and social studies. *Reading Rumba* comes from Primavera Publications, 481 Laidley St., San Francisco, CA 94131, phone 415/586-8244.

REASSURANCE: As our regular subscribers know, EMT's regularly scheduled March issue did not happen, as the editor was out of town doing things

having nothing to do with musical instruments. Be assured that all subscribers' expiration dates have been moved forward accordingly, and everyone will receive the full complement of issues they have paid for.

UP TO NOW the publisher has always managed to keep all of EMT's back issues and cassette tapes in print and available. We'll continue to keep the back issues available for the foreseeable future, mostly in the form of spiral bound, photocopied volume sets. But the expense and effort of keeping all six cassettes in stock has become too much for our humble operation, and so when the current cassette inventories sell out, we won't be making new copies of the back numbers. The first to go will probably be cassette volumes I and IV, so order them now if you want them (S6 per cassette for subscribers, from EMT at PO Box 784, Nicasio, CA, 94946).

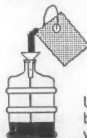


### Make great congas from plastic water bottles!

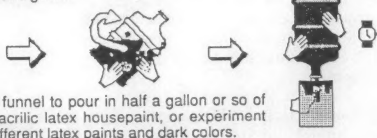
by Phil "Felipe" Pasmannick



Choose a clean, unbroken bottle that delivers a rich tone when slapped sharply just inside the bottom rim. *Alhambra* and *Albion Mountain Springs* bottles often sound good.



Use a funnel to pour in half a gallon or so of black acrylic latex housepaint, or experiment with different latex paints and dark colors.

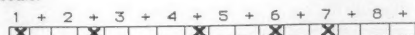


Swirl the paint around until the inside of the bottle is evenly covered. Then let the paint drain out for at least 72 hours or your drum will have unfortunate accidents on the floor when you play it.

Once dry, the paint inside the bottle will not chip or scratch, and the luster of the plastic gives your drum an attractive laquered look.



You can try to use several colors of paint inside, or paint the outside (much messier) or use tape or contact paper. All these styles of decoration tend to improve the sound of the bottle.



Finish your drum by cutting strips of 1" square ruled butcher paper to encircle the bottle. You will find the circumference to be just under 32 inches, or four bars of eighth notes (4x8=32). Use crayons, round stickers in bright colors, or markers to show two repetitions of rhythm patterns such as *clave* (above). Then glue the paper to the bottle. You may cover the paper with clear contact paper or wide cellophane tape to protect it.

## THE INSTRUMENTS OF QUBAIS REED GHAZALA

by Mike Hovancsek  
(from the technical notes  
of Qubais Reed Ghazala)

Several articles on the Theremin, a bio-modulated instrument, have appeared in recent months in various periodicals, and another is in the works, soon to appear in EMI. In examining bio-modulation and interactive electronic instruments in general it seems appropriate (if not mandatory) to discuss the instruments of Reed Ghazala as well.

Reed Ghazala is an inventor and an established visual artist who has his works in the Guggenheim, the Museum of Modern Art, and the Whitney permanent collections, in addition to numerous other display areas in three continents. As if this wasn't enough, Reed has also spent the last 25 years designing and building some of the most unusual instruments in the world including pieces that involve "wind, light, liquid, smoke, and player/viewer participation."

At the age of 14, Reed soldered together his first sound generator (the Odor Box) which created a bit of an uproar when it was used in performance (he had to smuggle his instrument out of the building in order to keep the audience from destroying it!)

Approximately twenty tapes and hundreds of instruments later Reed now records and performs as the central member of "Sound Theater" relying heavily on his huge collection of self-designed instruments including:

1) **Photon Clarinet** (this page center) — A light-modulated stepped-tone generator which produces clarinet-like sounds. Much like the Theremin, this instrument is modulated by the movement of the performer's hands over the instrument.

2) **Harmonic Window** (this page bottom) — Another bio-modulation instrument, the Harmonic Window is a sampler that can "stack series of sonic events and modulate loops into thick intense 'song cycles'".

3) **Solar Bug Box** (facing page top) — Built in 1981, this instrument is outfitted with six solar cells, two photo cells, and an elaborate system of digital circuitry. The myriad of switching, filtering and mixing combinations that this instrument is capable of producing range from jazz-like riffs to seemi-





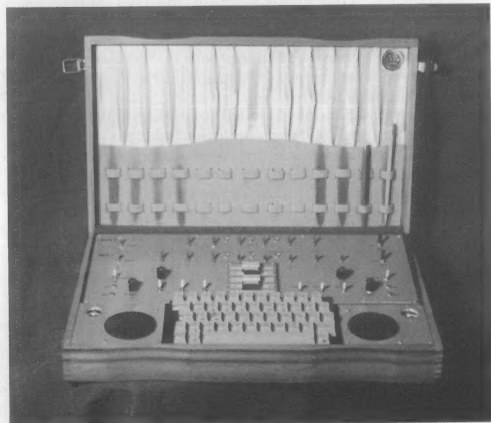
takes the solar Bug Box with him when he is camping and places it in a tree where the moving shadows of the leaves modulate the light source. According to Reed, "...it's interesting to walk past it at various times of the day to hear what different things it's up to in the changing light".

4) **L'esprit En Pieu** (this page, center) — Built for the 1989 Fusion Arts Festival in Paris, this interactive sculpture constantly samples and reinterprets nearby sounds into its own language.

5) **The R.A.P. (Readily Available Phonemes)** (this page below) — Based on the Linear Predictive Coding process of speech synthesis, this digital stereo instrument is best described by Reed:

Capable of standard speech, endless rhythmic abstract phoneme tracking patterns, and as a triggering source. Internally micro-processor-controlled and fully ported for external programming of extended composed phrasings. Two-voice system employs separate discrete amplifiers and built-in two-way speaker systems. Addressed through a QWERTY 49-key typewriter keyboard. Dual six-stage crystal banks for micro-processor time-bases. Six status and fourteen logic level LED indicators. Logic gate switching allows bits to either go high, low or float.

Reed Ghazala can be reached at 3325 South Woodmont Ave. Cincinnati, OH 45213. Plans are afoot for reports on several more of his instruments in coming issue of EMI.



#### SOUND DEVICES BY REED GHAZALA

Facing page top: Reed Ghazala with L'esprit En Pieu.

Center: The Photon Clarinet

Bottom: Harmonic Window.

This page top: Solar Bug Box

Lower left: L'esprit En Pieu.

Lower right: R.A.P. (Readily Available Phonemes)

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## BRIDGES: AN INDIAN PERSPECTIVE

By David R. Courtney, Ph.D.

## INTRODUCTION

The concept of the string instrument bridge and its function is quite curious. Those of us raised in the Western world have come to view the bridge as a ubiquitous component of stringed instruments. We see it as performing two functions: 1) it raises the strings off the resonator, and 2) it acoustically couples the strings to the resonator.

It will be shown in this article that the Indian concept differs slightly from the Western. We will see that in addition to the coupling and mechanical nature of the bridge, a third function is added. This function revolves around modification of the timbre. To this end ingenious mechanisms are commonly used. Let us briefly review the basic psychoacoustics of timbre.

Timbre is primarily a function of harmonic content. The simplest musical tone contains only a single frequency. As the timbre of an instrument becomes richer we see an increase in frequencies other than the main one. This main frequency is referred to as the *fundamental*. In most string and wind instruments the other frequencies are some multiple of the main frequency. These frequencies are called harmonics.

It should be noted that a sound composed of a single frequency rarely occurs naturally. We constantly hear sounds rich in harmonic content. The approach that musicians take to these components is one of the major differences between India and the West.

Western musicians have tended to look upon these harmonics as a form of tonal pollution which should be eliminated. The last few centuries of evolution of occidental musical instruments have generally been towards a suppression of upper harmonics with the enhancement of the fundamental.

Indian musicians have pushed their instruments in a totally different direction. An Indian musician considers an instrument whose tone is deficient in upper harmonics to be "lifeless" and totally unmusical. Therefore, very elaborate schemes have been developed to increase the complexity of the harmonic structure. Such approaches usually involve the bridge.

## BACKGROUND

India is linked to the West by being part of a larger family of cultures. This family is known as Indo-European and is broadly believed to have originated somewhere in the Middle East. Just as the languages show evidence of originating from some ancient Proto-Indo-European stock, the stringed instruments are said to have originated from simpler common instruments.

We find that in some of these archetypical instruments the bridge was totally lacking. In other cases we find an embryonic form which has a totally different function from present bridges.

Let us take the ancient harps as an example. (FIG. 1) These instruments appear to have been ubiquitous in the

Middle East during the millennia before the common era. In many cases they were simply a number of strings attached to the resonator. In the cases of a solid resonator there probably would have been no mechanical difficulties. However, in the case of a stretched membrane, there were problems associated with the skin itself.

FIGURE 1. Ancient Egyptian Harp



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Stretched skin is not as strong as the average solid resonator. Therefore, if an attempt is made to attach too many strings to the membrane there is always the possibility that it will tear. This is especially likely if peritoneum is used.

A simple mechanical solution exists for this problem. If a small piece of wood is attached to the skin and the strings attached to the wood, this distributes the tension evenly and reinforces the membrane.

This may have been the original purpose of the bridge. Such "proto-bridges" exist today throughout Africa and Asia. It appears that through the course of evolution its function of reinforcing the resonator was downgraded and the mechanical function of lifting the strings away from the resonator was emphasized. With the development of the first "true" bridge the requirement of effective acoustical coupling was introduced. The "true" bridge developed very early in history and evolved into the numerous permutations which are found today in Europe and Asia. While bridge forms in the west have rarely moved beyond the original purpose of acoustic coupling, incredibly advanced and complex forms evolved in India.

Today there are five types of bridge arrangements in the Indian subcontinent. 1) the "proto-bridge"; 2) the simple bridge on a solid resonator; 3) the simple bridge on a membrane; 4) the flat bridge; and 5) combination of flat bridge and membrane. Figure 2 is a diagrammatic representation of these five types.

## THE PROTO-BRIDGE

The simplest approach is the proto-bridge (FIG. 2a). Indeed the proto-bridge does not even have the characteristics

FIGURES 2 A – E (diagrams below): 5 types of bridges.

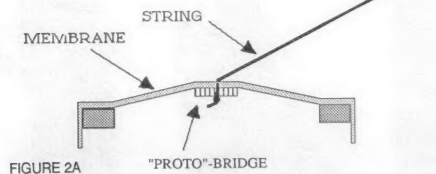


FIGURE 2A



FIGURE 2B



FIGURE 2C



FIGURE 2D



FIGURE 2E

COMBINATION

FIGURE 5 (below): Simple bridges with solid resonators on the surmandai (left) and santoor (right).

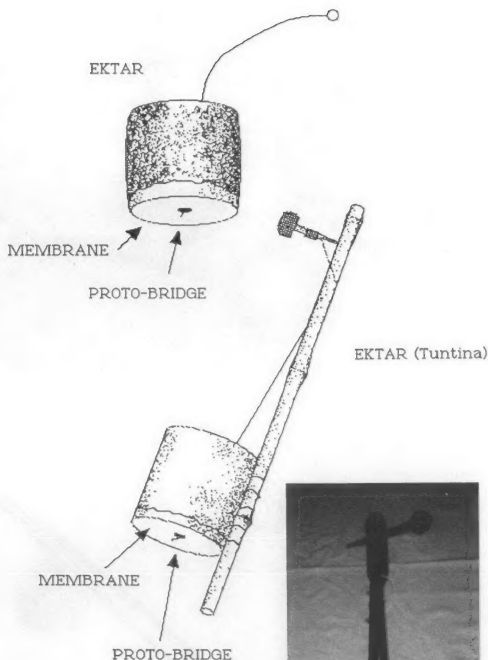
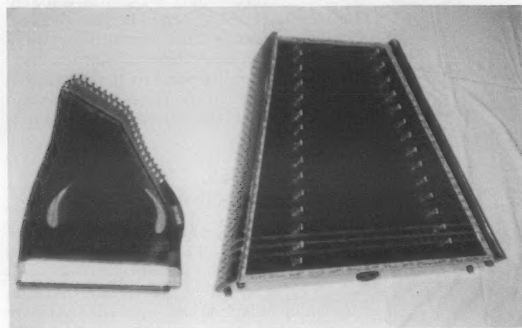


FIGURE 3 (drawings above): Folk instruments of the Ektar family.

FIGURE 4 (Photo at right): Another related instrument, showing the proto-bridge.

of the bridge as we think of it. The proto-bridge should be considered only because of its evolutionary relationship to the true bridges.

The proto-bridge is common in Africa but virtually unheard of in Europe. It is also very rare in India; however, a few examples may be seen in a class of instruments loosely referred to as *ektar* (FIG. 3 & 4). There are countless names to the various representatives of this family including *tuntina*, *gub-gubi*, and the *ananda lahari*. These are primitive folk instruments which are rarely heard.

## SIMPLE BRIDGES WITH SOLID RESONATOR

In India the simple bridge on a solid resonator is also quite rare (FIG. 2b.) This is in stark contrast to



FIGURE 6A

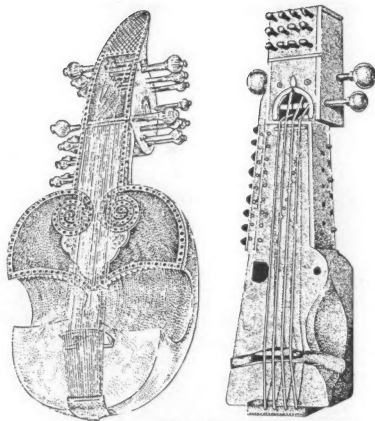


FIGURE 6B

#### INSTRUMENTS WITH SIMPLE BRIDGE ON A MEMBRANE RESONATOR.

FIGURE 6A (Photo above left), top to bottom:  
Esraj, santoor, kamakshi veena, ektar.

FIGURE 6B (drawings above right):  
Saringda and sarang.

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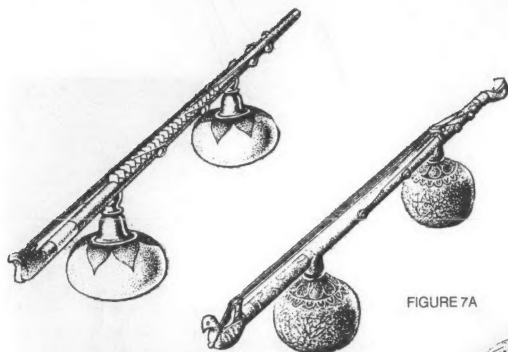


FIGURE 7A

#### INSTRUMENTS WITH FLAT BRIDGES

FIGURE 7A (drawings above and right, left to right):  
Vichitra vina, rudra vina, saraswati vina.

FIGURE 7B (photo below): Tamboura and sitar.

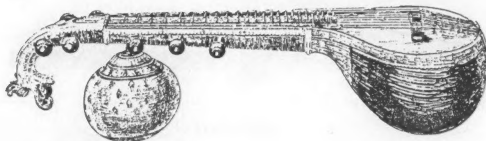
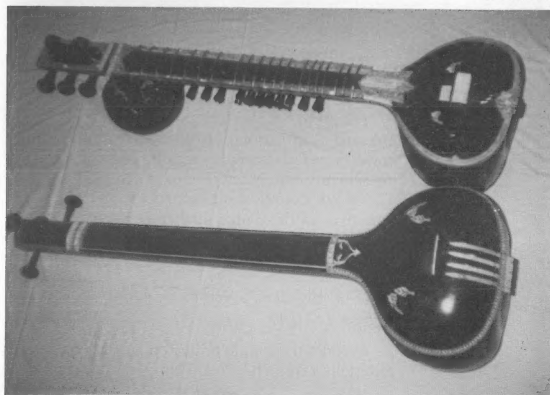


FIGURE 7B



the West where it is the norm. Guitars, violins, dulcimers, virtually every Western stringed instrument represents this type. In India, there are only two common instruments which display this approach and a third which occasionally shows it. These three instruments are the *santoor*, *surmandal*, (FIG. 5) and in very rare cases the ektar. I have only seen ektars using a solid resonator in the deep south.

#### SIMPLE BRIDGES WITH MEMBRANE RESONATOR

This is a very common class of instruments. These instruments all have a body upon which skin, peritoneum, or in a few low-cost folk instruments, paper is stretched (FIG. 2c.) Upon this membrane a simple bridge is placed. The nature of this approach means that the vibration of the

skin and the vibration of the string are both linked by way of the bridge. This approach is very rare in the West. The only common example is the banjo (originally of African origin). However, this is very popular in India. Common examples are the *sarod*, *esraj*, *dilruba*, *sarangi*, *saringda*, *ektar*, *dotar*, *ravin-hatu*, and scores of folk instruments too numerous to fathom (FIG. 6). Some of these instruments are plucked and some are bowed.

## FLAT BRIDGES

The previously described bridges are interesting, yet they pale in comparison to the flat bridge (FIG. 2d.) The flat bridge is unique in two areas. First, it is found only in the Indian subcontinent; and second, it has a very profound effect upon the timbre of the instrument. This bridge, often referred to as the *jawari*, is partly responsible for the "Indian" sound. It is found on instruments such as the *rudra vina*, *sitar*, *sarasvati vina*, *gotuvadyam*, *surbahar* and *tanpura* (FIG 7). The sitar is probably the most well known example of this bridge.

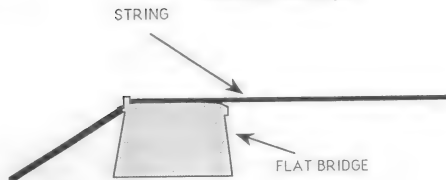
The term flat bridge is actually a misnomer. It is not really flat at all but has a gentle curve which is essential to the process of modifying the sound. Figure 8 is a diagram of this bridge.

The action of this bridge is not intuitively obvious. The easiest way to visualize it is to think of a guitar which has a warped neck. The characteristic buzzing of the warped guitar appears to be from the same mechanism which drives the flat bridge. That is to say that the "rattling" of the string against the bridge produces a characteristic pattern of overtones. [See EMI Volume II #6 page 10 - 11 for some additional brief notes on the *jawari*.]

Figure 9 shows the power spectrum of a typical note from the sitar. This note is a middle C. We may clearly see about 33 harmonics in this example. This represents an incredibly rich harmonic structure.

The case of the tanpura represents a slight variation upon this mechanism. Although the tanpura is technically a flat bridge, it is designed to be adjustable. This is accomplished by way of a small thread which is placed between the string and the bridge. When the position of the thread is just right, the timbre of the instrument is altered drastically.

FIGURE 8: Flat bridge



## COMBINED BRIDGES

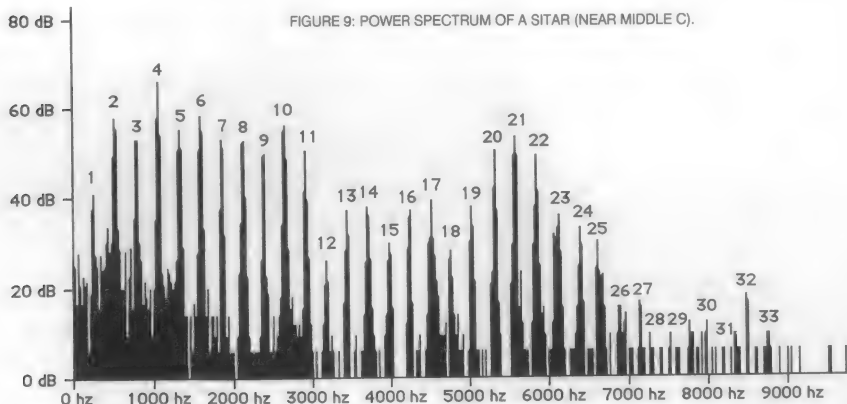
There are cases where a combination of flat bridge and membrane resonator are used (FIG. 2e). These are found in the drone strings of the *sarangi* and the *sarod*. Intuitively, one would expect the flat bridge to be placed upon the membrane directly. However, this is not the case. I suspect that it has something to do with the dimensional instability of the membrane. The physical characteristics of the membrane are known to vary tremendously with temperature, humidity, and tension of the strings.

Instead, when there is a membrane resonator the flat bridge is located on the neck, while a simple bridge is located on the membrane. In the case of the *sarod*, the strings are actually strummed. However, in the case of the *sarangi*, they merely vibrate sympathetically. It should be reiterated that this combination is very rare and appears to be confined to drone strings.

## CONCLUSION

We have seen that there are five approaches to the bridge in the Indian subcontinent. These are the proto-bridge, the simple bridge on a solid resonator, the simple bridge on a membrane, the flat bridge and the combination flat bridge/membrane. The purpose of these bridges has moved beyond simple mechanical functions to embrace the function of timbral modification. This has produced a variety of instruments which are far richer in their harmonic content than are generally found in the West.

FIGURE 9: POWER SPECTRUM OF A SITAR (NEAR MIDDLE C).



## THE TILL FAMILY ROCK BAND

by Dr. A M Till

*Some years ago, Dr. A M Till came upon an aged photograph showing the Till Family Rock Band. His progenitors, he learned, had toured widely in the British Isles in the 1880s, performing on a large lithophone made from stones gathered in England's Lake District. His interest piqued, Dr. Till began a search for further information on 19th century British rock music. In this article he reports some of his findings.*

This story begins in the Lake District in England and appears to end in New York.

The Till Family Rock Band originated in 1880 or thereabouts. The instrument is a 'lithophone' or xylophone made up of stones laid on a wooden trestle. From photographs it would appear that there are at least 50 stones in two layers but it would seem that it is unlikely to have corresponded with the modern chromatic scales. The stones were found in a specific valley in the Lake District area of North West England. Similar instruments were made by other families and are listed [in the sidebar at right, or below, or wherever the list appears] for reference.

The rock notes were struck with wooden hammers covered with felt. A description of the sound emanating from the instrument states that the tone was remarkably sweet and compares with the harp — the whole producing an effective instrument on which high class music could be performed.

More recent searches have discovered another set of ten stones in Ruskin Museum, Coniston — in the Lake District. Ruskin lived from 1819 to 1900 and was a poet, artist, critic and social revolutionary. He encouraged musicians and their talents and admired the rock band instruments, hence Daniel Till apparently made him a small set for his home called Brantwood.

I have in my possession an original English programme — undated — which gives some insight into the type of performance and musical items performed. We also have copies of musical scores used by the other family Rock Bands.

For some time my researches came to a full stop and I lost all hope that the Till Family Rock Band had survived. Via a circuitous route it is established that a Rock Harmonicon presented by William Till is in the Metropolitan Museum of Art, New York. However this appears to be a simplified version of only 21 stones (one broken) tuned diatonically on a simple wooden trestle.

Then came to light a copy of a Rock Band concert programme from America. The quality of photographic reproduction on this programme is not good but shows an instrument of stones in number more than the exhibit at the Metropolitan but fewer than the original English version. The Till Family also seem to have swelled their repertoire by playing on swinging harps and musical glasses. These additional instruments must have been more portable than the large lithophone which one can only assume was reduced in size for convenience on tour. Another reason may be that some stones may have been broken in transit and a compilation instrument produced which of necessity had a smaller range and number of notes.

Unfortunately the American programme is undated but the address given is William Till, 715 Ave C, Bayonne, New Jersey. Photographs of the Rock Band cost 10 cents on application!

The last 'gem' to be rescued from America and to come into my possession is a reproduction postcard showing the original sized instrument being played by William Till and three ladies (Mildred, Esther, ?). The reverse of the postcard states "From Stars and Garters, Copyright © 1983 by Gotham Book Mart & Gallery Inc., New York City" - Also "Steam Press, P0 BOX 16, Cambridge, Massachusetts 02144." Correspondence with both these addresses has failed to produce any response.

I am delighted to have the opportunity to present this article for this magazine and would be indebted to anyone who can help with any additional information. Who knows, there still may be a further small set of musical stones remaining as leftovers from the original large instrument which obviously did make its way to the U.S.A.

Dr. A M Till  
12 Larkspear Close  
Gloucester GL1 5LN, UK

LITHOPHONES AND THEIR MAKERS  
IN 19th CENTURY ENGLAND

## Peter Crosthwaite's Set of Stones (16 stones)

1785-1869 — In private hands  
1870 — Given to Fitz Park Museum, Keswick, UK

## Richardson's Rock and Steel band (60+ stones)

1827 to 1840 — Building  
1862 — Performing in concerts  
1862-1900 — In possession of  
James & Richardson Henderson  
1901 — Left in care of Fitz Park Museum

## Till Rock Harmonicon

1869-80 — Building  
1880-1887 — performing in England, Scotland,  
Europe and America

## Abraham Instrument (58 stones)

1886-98 — Building  
1898-1977 — In a private museum  
1982 — with Mr W Chamberlain in Reading, UK

## Small sets of stones - located as follows:

Elterwater stones — Fitz Park Museum, Keswick  
Mr. Byers — Applethwaite, Nr Keswick  
Single octave — Lancaster Museum, UK  
Single octave — Miss Dorothy Till, Lancaster, UK  
Harriman Museum Stones —  
Set of 21 stones, London



Above: Members Till Family Rock Band members with the Rock Harmonicon.

Below: Program from a concert presented by the Till Family Rock Band, date and locale not given. This and other surviving programs and promotional flyers overflow with testimonials as to the wonder of the instrument and the skills of the players, such as this, from Chambers' Journal (London):

"This is not a mere musical curiosity, but an effective instrument, producing most delightful music. The very rocks and stones are unconsciously possessed of a latent spirit of delicate melody, and touched as by the magic wand of an enchanter emit sounds so rich, full and sweet that they leave the ear and heart literally charmed with a power of fascination perfectly irresistible."

★ A Grand Concert ★  
WILL BE GIVEN BY THE CELEBRATED

## ROCK BAND

(TILL FAMILY)  
INSTRUMENTALISTS & VOCALISTS!

Who have appeared with great success at the Crystal Palace, Glasgow City Hall, Birmingham, Liverpool, and have just completed a most successful tour through Edinburgh, and the principal Towns in England, Scotland, and Wales.

Miss Till, Soprano. Mr. D. Till, Tenor.  
Miss Annie Till, Contralto. Mr. William Till, Bass.  
THE ROCK PLAYERS.—Messrs. Charles Till & Sons.  
PIANIST.—Mr. William Till.

FIRST ENTERTAINMENT—COMPOSED ENTIRELY OF A SELECTION OF NEW

### Songs, Duets, and Quartettes

Humourous Sketches,  
Violin, Zither, Klaphorn, Streich Zither, Musical  
Nails, Ocarina, and Gigliera Solos, Ocarina Quartets,  
and their Marvellous Performances on  
THE ROCK HARMONICON!

Will be accompanied by the celebrated American Pianist, Mr. J. W. Lawson, and  
the celebrated American Vocalist, Mr. J. W. Lawson, and the celebrated American  
Instrumentalist, Mr. J. W. Lawson, and the celebrated American Instrumentalist, Mr. J. W. Lawson.

From Mr. W. Lawson, M.P.  
"I had the pleasure of attending your Rock Band Concert the other night, and I  
thought—"

From Professor Russell:  
"I am extremely gratified to have seen your Rock Band, and to have witnessed the  
performance of the Rock Harmonicon, which is a most wonderful instrument, and  
the players are of the highest quality."

at THE TILL FAMILY'S Grand Concert, presented by the Chamberlain the Com-  
tinent, at the termination of which they will spend winter years in America.

Rock Band Concert.

### Programme.

PART I.

FANTASIA	"Sensational" (Hector)	ROCK BAND
PART SONG	"Queen of the Night" (Hector)	See Words
OCARINA SOLO	"American Air" (Hector)	See Words
NEW SONG	"The New Song" (Hector)	See Words
VALTSE	"Frisco Hills" (Hector)	ROCK BAND
AIR	"The Hills" (Hector)	See Words
DUET	"The Hills" (Hector)	See Words
FAIRY BELLS AND THE MUSICAL GLASSES	"The Hills" (Hector)	See Words
PART SONG	"The Hills" (Hector)	See Words
IMITATION OF THE MOUNTAIN GALE	"The Hills" (Hector)	See Words

INTERVAL

PHOTOGRAPH, 6d. 1s. and 2s. 6d. each.

PART II.

SELECTION	"The Hills" (Hector)	ROCK BAND
SELECTION	"The Hills" (Hector)	See Words
DUET	"The Hills" (Hector)	See Words
AIR	"The Hills" (Hector)	See Words
PIECE	"The Hills" (Hector)	See Words
SONG	"The Hills" (Hector)	See Words
SELECTION OF THE VALTSE	"The Hills" (Hector)	See Words
HUMOROUS TRIO	"The Hills" (Hector)	See Words
FANTASIA	"The Hills" (Hector)	See Words

"Copies of this Vales may be had in the Hall, 2s. each."

Permanent Address—TILL FAMILY, Norwich, Cumberland.

# AIR COLUMN SHAPES FOR WINDS

## BASIC PRINCIPLES

### Part I

by Bart Hopkin

This is the first of a series of articles that will be appearing in *Experimental Musical Instruments* dealing with practical wind instrument acoustics. In this issue and the next we present the two halves of an overview of wind instrument bore shapes, and how different shapes affect sound and playability. Following that will be an article on toneholes: their function, design, placement and sizing, along with practical tips on making them. Both topics, bore shapes and toneholes, are ones that EMI's readers have often called for.

My qualifications as a writer in these subject areas, I should acknowledge, are not the strongest. As with the articles on musical string design that I wrote for EMI a couple of years ago, I have tried to make up for this with a combination of careful research and, more importantly, suggestions and criticism of the manuscript from knowledgeable people.

Some of the material covered here is fairly dense. For a concise and easy-to-read presentation of similar material — less detailed, but eminently practical — I recommend Mark Shepard's *Flutecraft*, available from Monty H. Levenson, Tai Hai Shakuhachi, PO Box 294, Willits, CA 95490.

## BACKGROUND: BASIC MECHANICS OF OSCILLATION IN ENCLOSED AIR CHAMBERS

Most wind instruments do what they do by means of a partially enclosed air chamber. The chamber may be a hollow tube, or, less often, a globular form. The air within such enclosures has a natural inclination to resonate at certain frequencies. Wind instruments take advantage of this predisposition by exciting the air at one of those frequencies to produce an audible tone. Different instruments go about exciting the air in different ways: Reed instruments and lip-buzzed instruments ("brass") excite the resonant frequencies by forcing a stream of air past some sort of gateway that allows the air to pass into the chamber in rapidly pulsing bursts. Flutes do so by creating a situation in which air flow patterns at the edge direct the flow in rapid alternation first into the chamber and then out. In both general cases, if all goes well, the rate of pulsation or alternation comes into agreement with one or more of the resonant frequencies of the enclosed air, and with this cooperation established, the system speaks with a well-defined tone.

Air chamber resonance plays an important role in several other musical instrument types as well. These include percussion aerophones (in which the enclosed air is excited by some sort of direct percussion), marimbas with resonator tubes, stringed instruments with enclosed sound chambers, and various sorts of tuned drums. Air chambers designed to resonate at specific frequencies also have potential to be effective in some unfamiliar applications, such as in instruments using tuned tongues or strings with individually tuned air resonators, but these possibilities have only rarely been exploited.

Clearly, it matters a great deal just what frequencies the air chamber happens to resonate at, since that's the primary factor determining sounding pitch. Learning to control those resonances is the heart of the art of wind instrument making. The resonant frequencies of the enclosed air are determined primarily by the size and shape of the enclosure. That's what we'll be studying here — how resonances within the chamber function, and how the form of the chamber affects them in predictable ways. Let us begin by considering how the resonant frequencies come about.

Consider a simple cylindrical tube open at both ends. If an impulsive disturbance of some sort takes place at one end of the enclosed column of air — let us say someone whacks one open end with a soft, heavy, flat beater — it will create a localized increase in air pressure at that end. The pressure front does not stay put, but, behaving in classic wave-like fashion, immediately begins to propagate outward. Some of it escapes through the proximate opening, and the remainder, having nowhere else to go, proceeds down the tube toward the far end. The individual molecules of air involved in this mass action need not flow down the tube as part of the wave; each molecule need only move a tiny bit, and in so doing, transfer its energy to its immediate neighbor, thus doing its part in the propagation of the pressure wave front. When the pressure wave reaches the end of the tube, it encounters open air. It finds that the open air differs from the enclosed air in the manner in which it absorbs and propagates wave motion. This change is in effect a change in medium for the wave. At this transition point, a part of the wave energy is reflected back into the tube, while the remainder manages to move beyond the partial barrier, and propagates out into the room. The reflected wave is inverted: the pressure pulse becomes a negative pressure pulse (i.e., a rarefaction). It travels back up the tube, until it arrives again at the other open end. There it once again partially reflects: some energy continues into the open air as an ongoing wave front, and some stays within as the reflected portion, once again inverted, travels back down the tube. This process repeats at each end until the all the wave energy has been dissipated into the open air. In the current example that dissipation will occur fairly quickly, since we've provided no means for introducing more energy into the system, but typically it will still be a long enough time for the pattern to be established through a goodly number of reflections. Meanwhile, the series of pressure wave fronts that escaped the tube ends and propagated through the open air make up the vibration that a listener actually hears. Its frequency and associated pitch corresponds to the time between wave fronts, which is the time it takes the wave to reflect back and forth within the tube.

(Had one end of the tube been closed with some sort of rigid stopper, reflection would likewise have taken place there, but with these differences: wave energy would not have escaped into the atmosphere at that end, and the reflected wave would not have been inverted.)

Now there are several important points to highlight here. The first is the crucial nature of this business of partial reflection at the open end. If the entire wave were to reflect rather than just a part of it, the result would be a tube which does a wonderful job of sending wave fronts back and forth with very little energy loss — but it would be musically useless, because it would be unable to communicate with the outside world. No one not actually inside the tube would be able to hear it. At least part of the wave pulse must escape in order to move

the air outside of the tube and give us something to listen to. At the opposite extreme, if none of the wave were to reflect and all of it were to propagate into the open air, the initial impulse would simply run down and out the end of the tube; nothing would return and as a result there would be no resonance. At least some reflection is necessary to set up the pattern of oscillation in the tube. Partial reflection at an open end is thus an essential component in the successful operation of wind instrument tubes.

Secondly, let us highlight the way that the travelling waves described for the open tube give rise to vibration of the air at individual points in the tube. Assuming that the tube is not ridiculously long, the sequence of wave transmissions and reflections that took several sentences to describe above actually take place quite rapidly (no surprise), due to the speed with which sound pressure waves travel in air. The time it takes the initial impulse to travel to the opposite end, reflect and return depends upon that speed — which we can regard as a constant — and the length of the tube. So for a tube of a given length, there will be a defined frequency with which the wave reflects back and forth. This means that the air at any individual point in the tube will repeatedly be pushed one way and then the other at that frequency as the waves pass. So while we envision waves travelling, we can also envision individual air molecules vibrating, at frequencies determined primarily by the length of the air column. (There may also at the same time be some air flow through the tube, but this doesn't interfere with the basic thinking here.)

Travelling waves which repeatedly reflect back on themselves to create vibrations at a set frequency as described here can be called standing waves. It is often useful to view wave motion in this more static way — that is, focussing on the oscillation of individual points, rather than following the travelling wave motion.

Standing wave vibration in wind instrument air columns can be seen in terms of two complementary manifestations. One is displacement, which is to say, the actual oscillatory movement of the air molecules. The other is pressure change: the periodic variations in air pressure above and below the atmospheric norm for each point along the tube. To make the distinction clear, we can look at two extreme cases.

1) In an air column with one end stopped and one end open, the enclosed air immediately adjacent to the **closed** end will have essentially *no displacement amplitude*, since it really can't go anywhere without either hitting the wall or creating an untenable vacuum. At the same time, it will experience a *maximum of pressure variation* since it's constantly being squeezed or unsqueezed by surrounding air movement, with no place to go itself.

2) Conversely, the air just inside at the **open** end of a tube will experience essentially *no pressure variation*, because, having easy access to the wide world of unrestricted air outside, it can easily accommodate pressure changes through its own movement in or out. It will accordingly manifest a *maximum of displacement amplitude*.

Pressure and displacement, it turns out, always appear in this inverse relationship: in a standing air column wave, a point of maximum pressure variation, better known as a *pressure antinode*, will always be at the same time a point of minimum movement, or *displacement node*. A quarter wavelength's distance down the tube will be a point of minimum pressure variation, or *pressure node*, which is at the same time a point of maximum movement, or *displacement antinode*. Both aspects of the wave form — pressure and displacement — are important in conceptualizing wind instrument behavior (see figure 1).

We can now be clearer about this magic word *resonance*,

FIGURE 1



At the stopped end of this tube, air within is blocked, and cannot move in response to adjacent air pressing against it or pulling away. Remaining stationary, it undergoes maximum pressure variation, functioning as a *pressure antinode* (point of maximum variation in pressure) and a *displacement node* (point of minimum movement). The dense stippling represents this area of high pressure variation. (Note the key word here, *variation*. The stippling does not represent high pressure at any given moment, but rather continuing oscillatory change in pressure resulting from the standing wave.)

At the open end of the tube, the air is more free to move than anywhere else in the tube, and so can accommodate pressure changes in adjacent air with its own movement. It thus functions as a region of minimum pressure variation (*pressure node*) and maximum movement (*displacement antinode*). This area of maximum movement is indicated by the double-headed arrow.

which up to now we've been using without benefit of a definition. We have seen that wind instrument tubes have an innate preference for vibrating at certain frequencies, such as that corresponding to one round trip of the pressure wave of the open tube. (Other sorts of acoustic systems have analogous mechanisms giving rise to similarly preferred frequencies.) Such vibrating systems show a marked capacity for self-reinforcement and self-perpetuation at these frequencies. *Resonance* refers to the enhanced vibratory response of a system driven at frequencies at or near one of its preferred frequencies.

Such frequency-specific response is illustrated by our earlier example in which an open-ended tube, given an all-purpose generalized-frequency thump at the end, selectively vibrates at the tube's preferred frequency above all others. A still richer resonance response will arise if one can introduce into a tube an ongoing series of impulses at one of the resonance frequencies. Then the input oscillation and the tube's natural preferred vibrating frequency will happily reinforce one another. The same tube is likely to prove unresponsive to input at unrelated frequencies.

The presence of well-defined resonance frequencies is the essential element in the musical operation of wind instrument tubes. The mechanisms that create the pulsing of the air entering the tube — reeds, buzzing lips, or edgetone arrangements — are designed so that they can be at least partially dominated by the air column. The tube, with its marked preference for a certain frequency, can then induce the reed or lips to accommodate their pulsing rate to that frequency. That, briefly stated, is why a certain fingering on a clarinet produces a certain pitch: the clarinet tube having that particular configuration of open tone holes has a natural resonance frequency corresponding to the intended pitch, and the compliant reed (with encouragement from a skilled player) accommodates the tube resonance by pulsing at the same frequency.

The question of how these resonances play themselves out in tubes and air chambers of various shapes is the main item on our menu now.

## BASIC CONSIDERATIONS FOR WIND INSTRUMENT BORE SHAPE

Wind instrument air chambers can be and have been made in an infinite variety of shapes. The most familiar wind instruments, including both woodwinds and brass, are usually thought of as either conical or cylindrical; but in fact, almost all professionally-made winds contain substantial deviations

from the nominal ideal. This becomes especially apparent when one takes mouthpiece interior shapes, flared bells, and the small side-cavities associated with closed tone holes into account. A very different sort of air chamber shape can be seen in globular flutes, such as ocarinas. Here the enclosure takes the form of a fully three-dimensional volume of air, rather than an elongated column. Globular air chambers operate by different principles than long air column instruments, and we will discuss them later in this article. Particularly extraordinary are some of the air chamber shapes seen in pre-Columbian Central and South American flutes and whistles. The most intriguing of these are complex, multifaceted and beautiful in form, and correspondingly complex and strange in acoustic behavior. Their acoustic systems are highly idiosyncratic, and seemingly not designed for the kind of analyzable, replicable and controllable standing wave patterns that modern builders normally strive for. We won't attempt to elucidate their acoustics in this article. (Good luck to anyone who does attempt to do so.)

This brings us back to the bread and butter instruments, those familiar winds with elongated air columns. To begin to get a handle on the reasoning behind their shapes, we should become acquainted with the idea of "regimes of oscillation" (a term coined by the acoustician who did the most to develop the idea, Arthur H. Benade). I indicated before that musical instrument tubes typically have not one, but several resonant frequencies. When multiple resonances co-exist in the same air chamber, their frequency relationships influence their interaction and the sounding results in a number of ways. If, for instance, one resonant frequency in the tube is exactly twice another (making them an octave apart), the two can work together to make a good team. They fall into a mutually supportive lock step, and a regular pattern of reinforcement between the two arises. If the air column is induced to vibrate at the lower frequency, it will tend to bring the upper into play as well, creating a stronger resonance and a richer sound. No such pattern of reinforcement will arise between two resonance frequencies that do not bear the same sort of simple arithmetic relationship to one another.

In general, sets of coexisting resonances will fall into these self-reinforcing patterns whenever they are members of a harmonic series. [A harmonic series, by definition, is a set of frequencies consisting of a given fundamental frequency and its integral multiples — that is, frequencies  $f_1, f_2, f_3, f_4 \dots$  such that  $f_2 = 2 f_1$ ;  $f_3 = 3 f_1$ ; etc.] When a wind instrument player plays a particular note, the intended pitch normally corresponds to one of the lower resonant frequencies available in the tube given the particular fingering. That resonance can be thought of as a fundamental implying a harmonic series above. If several members of that harmonic series happen to be present as additional resonance peaks in the air column, then they will join in reinforcing the tone. The more that take part, the better the reinforcement. In well-made classical wind instruments, it generally turns out that for most of the instrument's fingerings, at least two or three resonances falling within the harmonic series of the intended pitch are available, making for a tone that is stable, strong and rich. If no resonances coinciding with the intended pitch's harmonic series are available, the tone will generally be weak, unstable and recalcitrant. In practice, any individual wind instrument will typically do better on some notes than others, with the result that the instrument may sing beautifully on some pitches and not as well on others.

The harmonic relationships between a tube's available

resonances are important in another respect as well. In order to achieve a wider range, classical wind instruments play in two or three "registers". A certain series of fingerings allows the player to produce an ascending scale in the lower part of the instrument's range; this is the lower register. The player can then cause the instrument to jump to a higher tone — often a fifth, octave or a twelfth up from the original low tone — and repeat a very similar set of fingerings to continue the ascending scale through a second, higher register. A third register may be available above the second. The upper registers come about when, for a given fingering, the lower of the tube's resonances is somehow inhibited from sounding, and a higher resonance comes to the fore to act, for sounding purposes, as the fundamental. (How the player causes this to happen will be discussed in an article on tone holes soon to appear in these pages). The important thing to note here is that if those higher resonances are out of tune — if, for instance, the second resonance peak for a given fingering is a bit less than an octave above the lower one — then the second register note for that fingering will be out of tune. Thus, a well-tuned harmonic overtone series in the tube's resonance peaks ensures that the instrument's upper registers will be in tune.

These ideas now enable us to see why acousticians and builders grant a certain primacy to the straight-sided cylinder and cone shapes for wind instrument tubes (even if only in the conceptual ideal). The vast majority of possible tube shapes (curvingly flared shapes, lumpy shapes, etc.) do not produce resonance peaks coinciding with the tones of a harmonic series. Among those that do, many would lose this property if their shape were to be altered by shortening or lengthening the tube. This last consideration is important ... here's why: Most wind instrument tubes are designed to play more than one note, and they usually do so by some method which effectively alters the sounding tube length, such as toneholes, valves, or slides. Cylinders and elongated straight-sided cones, it turns out, are the most practical forms capable of producing a harmonic overtone series in their resonant frequencies, *that retain that ability even when the tube is shortened*. One can use them to make an instrument playable over a range of different effective lengths without causing the overtone series to go out of kilter. This helps ensure that the tone will retain something like the same quality and richness throughout the range, and that the upper registers of the instrument, should they be used, will be in tune with the lower.

With all this talk about the sacred harmonic series, let me say once again that adherence to the series represents only a theoretical ideal for most long-tube wind instruments. And in many cases, for an open-eared experimenter, it may not have to be an ideal at all. While irregularly-shaped, non-harmonic tube instruments may lack the timbral fullness, volume and pitch stability of their harmonic brethren, many will nonetheless make musically useful sound. Interesting and unusual timbres can arise, as well as interesting and unusual pitch and scale relationships.

## DIFFERENT BORE SHAPES AND THEIR ACOUSTIC EFFECTS

OK, let us now look at standing wave patterns and the resulting wavelengths and pitches for the most universal tube shapes.

If we limit ourselves to cylindrical and conical tubes, we can see three basic forms: 1. Cylindrical, open at both ends; 2. Cylindrical, closed at one end; and 3. Conical. (Other variations turn out not to be practical for reasons you will recognize if you try to envision them.)

A. CYLINDRICAL BORE



B. CONICAL BORE



C. CYNICAL BORE



D. COMICAL BORE



### Cylindrical tubes open at both ends:

This category incorporates unstopped flutes, including fipple flutes (those with recorder-style mouthpieces), since the flute blow hole or edge hole acts as an open end. It also includes some percussion aerophones, and a few other odds and ends.

It will help us to analyze the possible standing wave patterns for this shape, as well as others, if we consider certain physical requirements that inevitably arise at the tube ends. Both ends of the open tube must represent points of maximum movement and minimum pressure change, since the air at the ends is uniquely free to move rather than withstand a pressure increase. Only standing wavelengths which happen to meet this requirement — that is, waves of the right length to have a pressure node/ displacement antinode at the open ends, given the tube length — will “fit” in the tube correctly. Other wavelengths are disqualified; they’re not capable of setting up as standing waves in the given tube length. In the simplest mode of vibration that does meet this requirement, the center of the air column becomes a point of minimum movement and maximum variation in air pressure (a displacement node/pressure antinode). Moving air on both sides alternately rushes in toward the center in response to low pressure there, and bounces back away from it in response to the resulting pressure build up, causing once again a low pressure point there and allowing the cycle to repeat. The result can be diagrammed as shown in the top section of the figure 2 and figure 3A (next page). Notice that the diagrams show the same events in two manifestations — as oscillations in air pressure, and as oscillatory movement of the enclosed air.

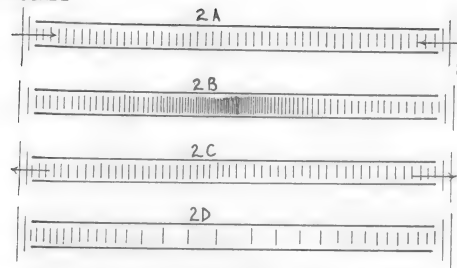
A wavelength, for a standing wave such as this, can be defined as the distance from one point of maximum displacement to the next point of maximum displacement in the same direction at a given instant (or alternatively, with the same

result, as the distance from one point of maximum pressure to the next point of maximum pressure). Notice on the diagram overleaf that the displacement antinodes at the ends of the tube move in opposite directions at any given moment. Thus the distance between them does not represent a full wavelength. The open-ended tube encloses one half of the fundamental wavelength. The full wavelength would theoretically end at a pair of displacement nodes located at a point one quarter of the tube’s length away from each end. (These nodes don’t actually exist, since outside of the tube the oscillations propagate themselves as travelling waves and the standing wave is not manifest.)

Since frequency is inversely proportional to wavelength, knowing the wavelength associated with a particular tube allows you to determine what its frequency and sounding pitch will be — roughly, at least. In part two of this article we will spell out more precisely how to make this determination.

The mode of oscillation just described represents the longest wavelength and lowest frequency resonance peak for the open cylindrical tube. It is considered to be the first, or fundamental mode. Other modes will be those additional standing wavelengths that “fit” in the open-ended tube by virtue of having displacement maxima at the open ends. The next two are diagrammed in Figure 3B and 3C. The standing wave for the second mode (Figure 3B) is half as long as the first, so that one full wavelength is enclosed in the tube. Its frequency is thus twice that of the fundamental (given the inverse relationship just mentioned), or an octave higher. The third mode (Figure 3C) has one third the wavelength and three times the frequency of the fundamental, producing a tone a twelfth higher. The fourth, fifth and higher modes continue this pattern. This sequence of resonances, you’ll notice, constitutes a complete harmonic series. Open cylindrical tubes will ideally produce their second register an octave above the first, and a third a twelfth above.

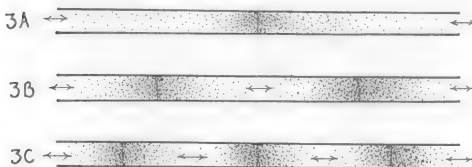
FIGURE 2



Air movement and pressure variation at four stages of the vibratory cycle for the first mode of vibration in a tube open at both ends. At the moment in time represented in 2A, air pressure is uniform throughout the tube, and in agreement with the atmospheric norm outside the tube. Uniformity of pressure is indicated by the evenly spaced vertical lines. But the situation is transitory, as an air movement into the tube from each end is taking place, as indicated by the arrows. At 2B, the inward rush of air has resulted in a high pressure region at the center of the tube; this build-up has counteracted the movement of air into the tube and at this transitory instant there is no air movement. At 2C, the pressure build-up at the center has caused an outward flow; once again we've caught the air column at its moment of even pressure distribution coupled with maximum movement. At 2D, the outward movement has created an area of low pressure at the center of the tube and the resulting inward pull is in the process of counteracting the outward air flow. Following this, the low pressure at the center will begin drawing air back into the tube; we'll return to the situation at 2A, and the cycle will repeat.

The wave form enclosed in the tube in this diagram represents only half of the full wavelength. To see this, recall that the full wavelength, by definition, extends from one displacement maximum to the next displacement maximum **in the same direction**. But in this particular mode, the air movements at the open ends are always opposite in direction. The full wavelength would end at a hypothetical displacement maximum (actually nonexistent) another half wavelength beyond one of the open ends.

FIGURE 3



The first three modes of vibration for a cylindrical tube open at both ends. Stippled areas represent regions of maximum variation in pressure and minimum movement, while the double headed arrows represent areas of maximum movement and minimum variation in pressure.

Mode 1 (the fundamental) encloses  $1/2$  of the full wavelength within the tube, to produce an approximate frequency of  $f_1 \approx v/2L$ .

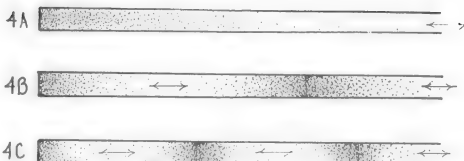
Mode 2 encloses one full wavelength, for an approximate frequency of twice the fundamental frequency, or  $f_2 \approx v/L$ . The sounding tone is about an octave above the fundamental.

Mode 3 encloses  $1 1/2$  wavelengths, to produce an approximate frequency of three times the fundamental frequency, or  $f_3 \approx 3v/2L$ . The sounding tone is about a twelfth above the fundamental.

Mode 4 (not shown) would enclose two full wavelengths for a frequency four times the fundamental, at  $f_4 \approx 4v/2L$ . Higher modes continue the pattern, with the generalized frequency formula  $f_n \approx nv/2L$ , where  $n$  is the mode number. The sounding tones proceed up the harmonic series, at 2 eves, 2 eves and a 3rd, 2 eves and a 5th, and so forth above the fundamental.

The end correction and other factors throw these results off slightly; see the list of formulas at the end of Part II of this article for more precise formulations.

FIGURE 4



The first three modes of vibration for a cylindrical tube closed at one end. Stippled areas represent regions of maximum variation in pressure and minimum movement, while the double headed arrows represent areas of maximum movement and minimum variation in pressure.

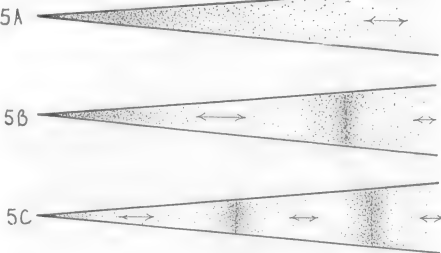
Mode 1 (the fundamental) encloses  $1/4$  of the full wavelength within the tube, to produce an approximate frequency of  $f_1 \approx v/4L$ .

Mode 2 encloses  $3/4$  of the wavelength, to produce an approximate frequency of three times the fundamental frequency, or  $f_2 \approx 3v/4L$ . The sounding tone is about a twelfth above the fundamental.

Mode 3 encloses  $1 1/4$  wavelengths, to produce an approximate frequency of five times the fundamental frequency, or  $f_3 \approx 5v/4L$ . The sounding tone is about two eves and a 3rd above the fundamental.

Mode 4 (not shown) would enclose  $7/4$  wavelengths for a frequency seven times the fundamental, at  $f_4 \approx 7v/4L$ . Higher modes continue the pattern, with the generalized frequency formula  $f_n \approx (2n-1)v/4L$ . The sounding tones proceed through the odd-numbered components of the harmonic series, at two eves and a very flat 7th, three eves and a 9th, and so forth above the fundamental.

FIGURE 5



The first three modes of vibration for a conical tube. Stippled areas represent regions of maximum variation in pressure and minimum movement, while the double headed arrows represent areas of maximum movement and minimum variation in pressure.

Unlike cylindrical tubes, with conical tubes the wavelengths implied by the locations of the nodes for a given frequency don't correspond to the wavelengths as they would appear in open air. And in fact, for physical reasons too complex to undertake here, the nodes within the tube are not evenly spaced, the first quarter wave section being stretched out to twice the length of quarter-wave sections farther down the tube. Although the internal waveforms look different, the frequency and (open air) wavelength calculations come out identical to those for cylindrical tubes open at both ends:

Mode 1 (the fundamental) encloses  $1/2$  of the full wavelength within the tube, to produce an approximate frequency of  $f_1 \approx v/2L$ .

Mode 2 encloses one full wavelength, for an approximate frequency of twice the fundamental frequency, or  $f_2 \approx v/L$ . The sounding tone is about an octave above the fundamental.

Mode 3 encloses  $1 1/2$  wavelengths, to produce an approximate frequency of three times the fundamental frequency, or  $f_3 \approx 3v/2L$ . The sounding tone is about a twelfth above the fundamental.

Mode 4 (not shown) would enclose two full wavelengths for a frequency four times the fundamental, at  $f_4 \approx 4v/2L$ . Higher modes continue the pattern, with the generalized frequency formula  $f_n \approx nv/2L$ . The sounding tones proceed up the harmonic series, at 2 eves, 2 eves and a 3rd, 2 eves and a 5th, and so forth above the fundamental.

## Cylindrical Tubes Closed at One End:

This category includes stopped flutes such as slide whistles, most panpipes and many organ pipes, plus some percussion aerophones and most tuned marimba resonator tubes. It also includes those reed and lip-buzzed instruments that are cylindrical over most of their length, such as the clarinet family and trombones. The latter groups fit the stopped-end description in part because lips or reed form a barrier at the end of the tube, and in part because they impart their pressure pulses at the same point where a stopped end would cause a pressure variation maximum. As a result, the wave form diagrams come out the same both for simple stopped ends and for cylindrical members of the reed & brass families.

The one open end of such a tube behaves like the open ends described above, serving as a pressure node/displacement antinode. The closed end is the reverse. The air that is immediately up against the closed end can't move to accommodate the motion of adjacent air; instead it remains stationary and undergoes maximum pressure variation. It thus becomes a displacement node/pressure antinode. In the case of reed and lip-buzzed instruments, the introduction of pressure pulses at this location contributes to this effect. We can diagram this as in figure 4.

The fundamental, or first mode of oscillation, is again shown at the top of the diagram. Notice that the stopped tube encloses not a half of the fundamental wavelength, as the open tube did, but half of a half — the distance from the stopped-end pressure maximum to the open-end pressure minimum a quarter wavelength away. Quarter-wave resonators such as this naturally have their lowest-frequency resonance at twice the wavelength of half-wave resonators like that shown in Figure 3. The closed tube fundamental frequency is thus half that of an open tube of the same length, and the fundamental pitch an octave lower. This makes closed tubes economical for achieving lower pitches: you can produce a given pitch in the lower register at half the tube lengths that open tubes would require.

In Figure 4B and 4C we can see the next couple of standing wave patterns for tubes closed at one end. The diagram shows an important result of the closed tube's natural requirement that there be a pressure variation maximum at one end and a displacement variation maximum at the other: the standing wave patterns that fit this configuration do not form a complete harmonic series. The first possible mode of vibration for the closed tube (Figure 4A) encloses one quarter of a wavelength; the second (4B) encloses three-quarters; the third five quarters (4C), and so forth. The resulting frequencies are three, five, seven and so forth times the fundamental frequency. We get a harmonic series impoverished of its even-numbered components. The absence of resonances to support the even-numbered harmonics contributes noticeably to the timbre of such instruments. It gives rise to a characteristic sound often described as dark or hollow, best exemplified in the lower register of the clarinets. The incomplete series also means that the second register for a closed cylinder instrument is a twelfth above the fundamental register; the third comes out at two octaves and the third.

## Conical Tubes:

True conical tube instruments are rare, since a complete cone would come to an end at a single point, rather than at, for instance, a mouthpiece-shaped body of air. But many

instruments approximate a conical form closely enough to take advantage of some of its acoustic properties. These include reed instruments such as oboes, and lip-buzzed instruments such as cornets. As with the cylindrical tube instruments described above, a reed or buzzing lips can take the place of the closed end of a complete cone, and so support wave forms similar to those that would arise in the complete cone. A glance at any of these instruments will verify that the cone angles of conical musical instrument tubes are not large. The largest angle among standard instruments is found in the saxophones at 3° or 4°, ranging down to about 0.8° for bassoon.

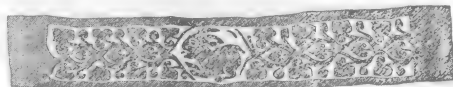
Standing waves in cones function much like those in cylinders with a stopped end, except for effects arising from the fact that the volume of air is not distributed uniformly along the tube, but increases proportionally toward the large end. This affects both the springiness and the mass of the enclosed air at different locations, with the result that the different sections of the standing wave — the distances between the nodes and antinodes — are not evenly spaced for different segments of the wave. Without going into the whys and wherefores, the practical result of this is that for musical purposes a given conical tube will behave much like an open cylindrical tube of the same length. The fundamental will be of the same frequency as the open cylinder (an octave above the stopped cylinder of the same length), and the wavelength will correspond roughly to twice the tube length. The resonance peaks will reflect a complete harmonic overtone series; the tube will be capable of a second register at an octave above the first, and a third register a twelfth above. Differences between the cone and the open cylinder do arise in connection with pitches resulting from shortening the tube — e.g., a tonehole at a specific location would give rise to different pitch changes on the two tube types.

An anomalous case is the recorders, with incomplete reverse-conical bores (they become narrower toward the far end, but are cut off short of the place where closure would occur and so are open at both ends). They behave much like other tubes open at both ends, producing the complete overtone series and overblowing the octave for the second register, but the tone hole locations must be displaced relative to what they would be in a cylindrical tube. The narrowness of the opening at the far end contributes to the conspicuous weakness of the lowest note or two.

In Part II of this article, scheduled to appear in this journal's coming issue, we'll make a stab at applying the principles discussed here to the rather more complex world of actual, playing wind instruments. See you then.

## ACKNOWLEDGEMENTS

Sincere thanks to Professor Donald Hall for his knowledgeable and insightful criticism of the manuscript for this article. Two books were used extensively in the preparation of this article, both of them excellent general texts on musical acoustics. They were 1) Donald Hall's *Musical Acoustics: An Introduction* — designed as a college level textbook, and accessible, lucid and practical throughout — and 2) Arthur Benade's *Fundamentals of Musical Acoustics*, another excellent, if more demanding and at times idiosyncratic, overview of the topic. A fuller bibliographical listing will appear at the end of part two of this article.



## HOW TO BUILD THE PIANORAD

### Construction of the Instrument Combining the Piano and Radio

By Clyde J. Fitch

Originally published in **Radio News** magazine, December, 1926.

*This is the third in a series of reprints currently appearing in EMI featuring early 20th century popular magazine articles devoted to unusual musical instruments. Radio News, the magazine that originally published this article, ceased publication in 1948. The article was brought to our attention by Ivor Darreg, who writes:*

"In spite of the Piano and Radio naming of the Pianorad instrument, suggesting that it is a blend of piano and radio set, it is really the first instance of an electronic organ for home construction that I can find so far. How to build a vacuum-tube organ 65 years ago! I was only 9 in February, 1927, when I saw this article at the home of one of my uncles in Portland, Oregon. It wasn't until I was about 56 that I ran across the magazine again at a back number store in L.A. and bought it.

"For a while, the Conn, Artisan, and Allen organs used this kind of vacuum tube circuit; also about six instruments in Europe in the 1930s used similar ideas."

While it may appear to the reader at first sight that the Pianorad is a complicated piece of apparatus, this is far from the truth. It is true that 25 vacuum tubes are employed, and radio set builders know very well the amount of labor required to assemble a five-tube set. Consequently the Pianorad is no more complicated than five radio sets; in fact, considerably less so because each tube in the Pianorad is wired like all the other tubes, whereas in a radio set the tubes are all wired differently.

In building the Pianorad, a radio console cabinet was first procured. The type used was found very adaptable, due to the fact that it can be completely closed up when not in use and occupies little space.

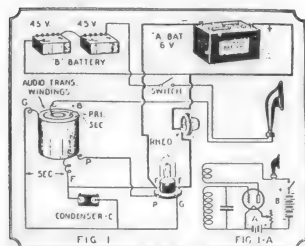


FIGURE 1 (above left) shows an audio oscillator connected as in the Pianorad, and FIGURE 1-A is the schematic diagram of the same..

Secondly, a two-octave keyboard, such as are used by beginners for practice work, was obtained. A set of contact springs was mounted under the keyboard in such a way that, when a key was depressed contact with one was made by the spring under the key, which is used to return the latter to its original position when released. In other words, each key acts as a switch and closes an electrical circuit.

But before going into the assembly of the apparatus, let us first discuss the theory of its operation. In the course of our experiments many interesting phenomena were observed and while the reader may have no intention of building a Pianorad, he will undoubtedly find a brief description of its action interesting.

### AUDIO OSCILLATOR CIRCUITS

We will start with a single-tube Pianorad; the connections are shown in Fig. 1. All radio set owners are familiar with the high pitched "squeal" sometimes produced by faulty audio amplifiers. It is this squeal, refined to a musical tone, that is made use of in the Pianorad. To obtain it at will, we first procure the windings of an audio-frequency transformer; any one will do. Simply remove the iron core, taking care not to break the fine-wire connections to the coils. The windings are then connected to a vacuum tube as indicated. You will note that the "B" battery current flows through the loud-speaker to the primary winding of the A.F. transformer, and through it to the plate of the vacuum tube. The secondary winding is connected between the grid and filament of the tube.

In this case the primary acts as a tickler, and oscillations are generated. Owing to the large amount of wire in the circuit, the oscillations are of an audible frequency and are manifested in the loud-speaker. It is important that the connections to the primary winding be made properly, because if they are reversed the circuit will not oscillate. The simplest way to find the proper connections is to try one way and then the other; the speaker will give out a loud squeal when the connections are correct.

### TUNING THE PIANORAD

Now we come to the problem of controlling this squeal, and making a musical tone out of it. First we connect a fixed

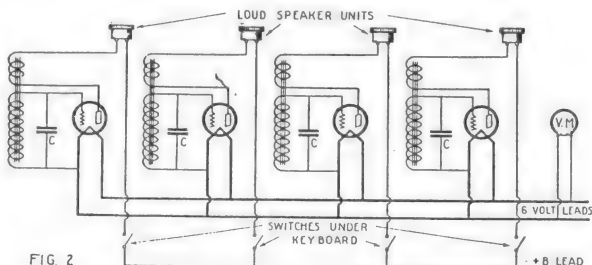


FIGURE 2: Connections of the oscillator tubes in the Pianorad. Only four tubes are shown here, the other 21 being wired similarly.

condenser (C) across the secondary winding as shown; immediately the squeal becomes much lower in pitch. By connecting condensers of different capacities across this winding, the pitch of the squeal will be correspondingly varied. The larger the condenser, the lower the pitch, and vice versa.

It is almost impossible to obtain fixed condensers of the exact capacities required to tune the circuit to a definite musical tone. Therefore, we connect across the coil a fixed condenser that gives a note rather near, but *higher* in pitch than the musical tone required; and then fine iron wires, or for that matter any small pieces of iron such as nails, are placed in the center of the windings, where the core was originally. As the iron approaches the coil the pitch of the tone lowers. Perhaps the correct note is obtained with a piece of iron wire half way into the coil. Some means, therefore, must be devised to hold the iron in position.

In building the Pianorad it was found that the simplest method is to fill the center holes of the windings with modeling clay, and then stick the iron wires into the clay. In this way a very gradual change in pitch can be made and it can be held constant at any desired value.

It was found that for the lowest tone of the Pianorad, which is one octave below middle C, or a frequency of 128 cycles per second, a fixed condenser of .02mf capacity was required. For the highest note, one octave above middle C, or a frequency of 512 cycles, no condenser was required. A few pieces of iron wire in the core were sufficient to lower the pitch to the desired value.

This *audio oscillator* of Fig. 1 will be found useful in the experimenter's laboratory for other purposes than that of generating musical tones. It may be used for testing loud speakers, transformers, and other radio apparatus.

Instead of connecting the loud speaker directly in the circuit of the vacuum tube, as shown in Fig. 1, it was first connected to a 1000-turn honeycomb coil, coupled to the transformer windings. (In fact the windings were placed inside of the honeycomb coil). Our first Pianorad comprised twenty-five oscillator tubes, one for each note on the keyboard, and twenty-five honeycomb coils, connected in series, and coupled to the oscillator windings. This arrangement was made in the belief that one loud speaker could be used for all tubes. The output from the twenty-five coils was amplified by a power tube, in the plate circuit of which was placed the loud speaker.

With this arrangement a very peculiar phenomenon was observed. When all the circuits were accurately tuned, the music played on the instrument was very melodious. However, a slight change in the pitch or frequency of one or more of the circuits, due to slight variations of the filament current or other causes, produced a very disturbing effect. For example, if middle C and high C were exactly in tune, the second harmonic of middle C would fall in phase with the fundamental of high C, and the two notes would harmonize. If either of the notes fell slightly out of tune a powerful beat would result and when chords were played, this was very serious. As in the superheterodyne, the beat note is of a frequency equal to the difference between the two frequencies producing it; and in the above case, it is the difference between the frequency of the second harmonic of middle C, and the fundamental of high C.

As the beat note is considerably stronger than either of the two notes producing it, and as all three were amplified and then passed through the loud speaker, the interference caused

by the beat was so great that all musical harmony was lost. It is impossible to maintain the circuits in an absolutely constant state and the only alternative is to employ a separate loud speaker unit for each tube. By so doing, no beat note is produced until the sound waves interfere with each other outside. While the beat notes are present, they are so weak that they can hardly be detected by ear.

## SIMPLIFYING THE ASSEMBLY

The twenty-five loud speaker units are mounted on one sound chamber which opens out into a bell-shaped horn. Each unit is connected to its respective vacuum tube and switch on the keyboard. As adjustable units are used, the volume of each note can be regulated until all are uniform. It is obvious that, by the use of a separate unit for each note, the honeycomb coils could be eliminated; and each unit is connected to its respective plate circuit, according to Fig. 1.

Perhaps Fig. 2 will give a better idea of the connections. Here, only four tubes are shown; the other twenty-one, however, are all connected in like manner. A voltmeter across the filament terminals is required, because a slight change in filament current will throw the apparatus out of tune. When it has been once tuned at the proper voltage, it is necessary to adjust the filaments to the same voltage every time the instrument is to be played.

As the twenty-five type 201A tubes draw 6 1/4 amperes, a heavy duty 7-ampere filament rheostat, mounted on the back of the cabinet, is used. A "B" battery of 90 volts is sufficient; as "B" current is used only when the keys are depressed, the ordinary radio batteries are large enough.

The vacuum tubes, with their accompanying coils and condensers, are mounted on shelves and placed in the console cabinet. Each shelf has its filament and loud speaker binding posts; so that the connections to it can be removed and the shelf can be taken out for repair or other purposes.

The process of tuning the Pianorad is very simple. Of course, each tube is first roughly adjusted to the proper frequency by means of fixed condensers, after which the final adjustment is made by means of the iron wires placed in the center of the coils. Anyone with a musical ear and a piano or other musical instrument for comparison will have little difficulty in tuning the Pianorad.



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## SOUND BY ARTISTS

Dan Lander and Micah Lexier, editors

Published in 1990 by Art Metropole (788 King St. West, Toronto, Canada M5V 1N6) and Walter Phillips Gallery (The Banff Center, Alberta, Canada T0L 0C0).

Reviewed by Bart Hopkin

Art Metropole is an artist-run center for the arts in Toronto. One of Art Metropole's activities has been publication of artists' books, and the current title, *Sound by Artists* is their most recent in a series of anthologies of artists' writings. *Sound by Artists* contains essays by thirty-plus artists working toward an art of sound (a list of contributors appears below). There is also an extensive discography and bibliography.

In some of the pieces the writers simply describe one or more of their sound art works. Other contributions take the form of descriptive surveys of the work of many artists, while others, such as John Cage's important early manifesto, "The Future of Music: Credo" (1937), are philosophical inquiries. The submission of one artist (Christian Marclay) consists simply of a soundsheet (floppy vinyl record bound into the book) which is deliberately unplayable. Most of the writings, like the Cage Credo, have appeared earlier elsewhere. The others are more contemporary though — most come from the mid- or late 80s. Still, the writers are well-schooled in the history of art. References to aesthetic movements from earlier in the century figure prominently in many of the writings, with names like Russolo, Kandinsky, Brecht, Stockhausen, Varese, Partch, and Cage arising frequently.

The writers in this book do not talk primarily about music (although there's plenty of room to quarrel over definitions here). They speak about an art of sound in which the predominant parameters of music (melody, scale, rhythm dominated by metric pulse, and so forth) are not necessarily preponderant, and in which the aesthetic possibilities of sound are approached far more openly. Within this context, certain ideas and questions crop up repeatedly, and perhaps a good way to convey some sense of the substance of the book would be simply to list some of these issues:

1) The art and skill of listening with open ears. It is not uncommon for people either to ignore sound altogether or to respond to the message content of sounds without ever being aware of the character of the sounds themselves. Several writers in the anthology suggest, not surprisingly, that we could all learn to listen better. But they don't all simply advocate hearing sound exclusively in and of itself: sounds do have associations and meanings for listeners; sounds are capable of evocation; sounds are by nature contextual. In any art of sound, the semiological and associative aspects of sound must surely play an important, conscious role.

2) Relations between and comparisons between the aesthetic responses of the different senses. Many of the writers speak of sound in the context of other senses, and observe parallels or non-parallels between the aesthetic responses of the several senses. Some express an interest in synaesthesia, in which stimulation of one sense crosses with the sensations

of another. More generally, several of the writers are concerned with the question of why humankind's aural art tends to be so very different in nature from visual art: Aural art almost always takes the form of music which is created within highly restrictive conventions regulating the use of time and pitch space, while visual art has ranged over a far broader territory.

3) Recorded sound and its uses. Several of the essays address the question of the nature of the reality or unreality of recorded sound. While hi-fi ads have encouraged us to accept the idea that recordings at their best can be indistinguishable from natural sound, the fact is that the sounds of a symphony or a human voice or a lion's roar coming from a speaker box presents a very different reality from a symphony, a human or a lion. The questions thus pertain not only to acoustic fidelity, but to contextual displacement. Most of the authors seem to feel that recorded sound can play a central role in whatever forms an art of sound might take, especially if one treats contextual displacement in a conscious manner rather than as an anomaly best ignored. The primary role that recording currently takes is simply that of enabling us to reproduce existing music out of context, and this can be seen as a strangely restricted use of the possibilities. In addition, the sound-manipulating possibilities inherent in recording and related technologies are a central topic for some of the authors, especially in light of recent advances.

4) Political implications of the control of sound media. Several of the authors comment on ways in which radio, TV and recording serve the purposes of monied interests even as they cater to the perceived (artificially created?) appetites of the general population. Several make the observation that radio doesn't *have* to be what it has mostly become (e.g., series of 3-minute pre-recorded musical selections interspersed with human voices encouraging listeners to buy various products); that the technology of radio lends itself well to a far wider variety of uses both practical and artistic. This leads to the idea that artists, and people in general, would do well to try to reclaim some of this technology for themselves.

The preceding paragraphs represent a perhaps arbitrary sampling of ideas from the book. There is a lot more to be found within it: *Sound by Artists* is close to four hundred pages long, and every essay is full of things to say. Some of the writing is dry, I should warn, and it more-than-occasionally takes on an art-babble tone that turns to fluff within the reader's mind if he or she doesn't make an effort to concentrate on the content. But for a good look at contemporary thought on sound art, from some sophisticated and challenging artists and thinkers, this book is a fine resource, and a unique one.

Artists/writers contributing to *Sound by Artists*:

Daina Augaitis, Bruce Barber, Max Bruinsma, John Cage, Kevin Concanon, Moniek Darge and Godfried-Willem Raes, Suzanne Delahanty, Jack Goldstein, Graf Haufen, Ihor Holubizky, Douglas Kahn, Richard Kostelanetz, Christina Kubisch, Marysia Lewandowska, Annea Lockwood, Alvin Lucier, Christian Marclay, Donal McGraith, Rita McKeough, Gordian Monahan, Ian Murray, Mystery Laboratory, Maurizio Nannucci, Max Neuhaus, R. Murray Schafer, Stelarc, Rod Summers, Chris Towner, Bill Viola, Hildegard Westerkamp, Gregory Whitehead, Caroline Wilkinson.

# NOTICES

**NOTICE:** 1991 marks the 60th anniversary of Ivor Darreg starting to compose and also the 60th anniversary of his taking up the cello. Beyond that, 1991 is the 50th anniversary of the 5-string amplifying cello. 1992 will be the 30th Anniversary of the Lateral Network now known as the Xenharmonic Music Alliance. The first instruments of the Megalyra Group date from 1975.

I am researching musical instruments which use a diaphragm and horn to amplify and direct the sound of stringed instruments for use in the pre-electric recording process. Info pertaining to Stroh-viols, Tielel, Pásoold-violins, James Tann 1903 USA, Joseph Rapswe [sp?] 1928 USA and others very welcome. Gerhard Kress, 6 Maycliffe Park, Ashley Down, Bristol BS6 5JH.

**PLATE TRICHTONICS** is a new cassette tape from Tom Nunn, featuring his electroacoustic percussion boards (diverse scraped, struck and bowed things on a contact-miked soundboard, with electronic processing) and space plates (metal rods on a highly reverberant balloon-mounted sheet metal resonator, played by bowing). Available for \$8 plus \$1 shipping & handling, from 3016 25th St., San Francisco, CA 94110.

**ANYONE CAN WHISTLE**, direct mail consumer catalogue, seeks easy-to-play, high quality MUSICAL OBJECTS, INSTRUMENTS, RELATED GIFTS for musical explorers of all ages. Sturdy and safe. Send photos, literature or samples to ACW, PO Box 4407, Kingston, NY 12401.

**WANTED: USED CHAPMAN STICK.** About 3 years ago, I sold a virtually new Stick to pay the rent. Have been depressed ever since. If anyone wants to sell a Stick, please write Breck Nichols, 8906 Stanwood, Dallas, TX 75228.

**WANTED: UNUSUAL MARRIAGE PROPOSALS** for a book collecting 100 unique marriage proposals. Any involving musical instruments? Write a letter or make a tape; include full name and address for verification of details. All whose stories are selected will receive an autographed copy of the book. J. Clayton, PO Box 1222, Red Lodge, MT 59068.

Needed for a new edition of **Directory of Suppliers:** names and addresses for suppliers of all things used by instrument makers and restorers, including tools, materials and literature. Send to Mark Norris, The Old School, Stobo, Peebles, EH45 8NU, Scotland, GB.

**SOUND AROUND** is a directory of folk, folk-rock, acoustic and alternative music venues, geared for the self-bookings musician. Over 1000 listings for clubs throughout the US. Available by region (Northeast, Midwest, West, South) for \$10.00, or entire US for \$25. Sound Around, PO Box 297, Hadley, MA 01035.

**HOST-AGE** is an alternative music radio show on KSER 90.7 FM in Seattle, alternate Wednesdays 11 pm.

**JEW'S HARP FESTIVAL** Sumpter, Oregon, July 1-August 2, 1992. For information contact Gordon Frazier, PO Box 14466, Seattle, WA 98114, phone 206/725-2718.

**FLUTE MAKING BOOKS** by Mark Shepard, formerly from Simple Productions, are now available only from Monty Levenson, Tai Hei Shakhuchi, PO Box 294, Willits, CA 95490, phone 707/459-3402. Shakhuchi books are also available from Tai Hei.

The sixth biennial **SOUND SYMPOSIUM**, international celebration of sound, takes place this year at St. John's, Newfoundland, July 1 - 11. For information write 81 Circular Road, St. John's, Newfoundland, Canada A1C 2Z5, or Fax 709/753-4630.

**THE BONES** are an ancient wooden rhythm instrument of unknown origin currently played in Ireland and parts of the Eastern US. High quality bones available from Shooting Star Bones, 355 Carrol Ave., Felton, CA 95018; phone 408/335-9312.

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**JUST INTONATION CALCULATOR** by Robert Rich and Carter Sholz. A composer's tool for just intonation. Internal sound for tuning reference; microtonal ear training; shows modulations; reduces fractions; converts between ratios, cents, and Yamaha tuning units; MIDI tuning dumps for many brands of synthesizers. Requires Macintosh with Hypercard - only \$10.00. Soundscape Productions, Box 8891, Stanford, CA 94309 Now available:

Xenharmonikon Nos. 7-13, cassette by experimental Indonesian composer I Wayan Sudra. Soon to be published: John Chalmers' **Divisions of the Tetrachord**. Write for complete catalogs. Frog Peak Music and American Gamelan Institute, Box A-36, Hanover, NH 03755.

**QUARTZ CRYSTAL "SINGING" BOWLS**, frosted and clear in 12 sizes, in all musical notes available - magical - powerful healing tools for meditation and stress elimination, balancing energies, etc. Also available: handhanded square drums, hoop and dance drums as well as water and ceramic kettle drums, various types of RAINSTICKS, melodious chimes, bells, cymbals. Largest distributor, lowest prices. The CRYSTAL STORE 1-800-833-2328.

**EMI BACK ISSUES:** Back issues of **Experimental Musical Instruments** numbered Volume VI #1 and later are individually available for \$3.50 apiece. Earlier issues are available in volume sets of 6 issues each, photocopied and spiral bound: Volumes I through V, \$14 per volume. Order from EMI, PO Box 784, Nicasio, CA 94946, or write for complete listing. Corresponding cassette tapes also available for each volume; see information below.

**CASSETTE TAPES FROM EMI: From the Pages of Experimental Musical Instruments.** Volumes I through VI are available at \$6 per volume for subscribers; \$8.50 for non-subscribers (each volume is one cassette). Each tape contains music of instruments that appeared in the newsletter during the corresponding volume year, comprising a full measure of odd, provocative, funny and beautiful music. Our supplies of Volumes I and IV are nearing exhaustion and guess what? We ain't gonna press more of them when they're gone. Order from EMI, Box 784, Nicasio, CA 94946.

**MICROTUNAL MIDI TERMINAL** (vers. 1.2) by Denny Genovese lets you play nearly any MIDI synthesizer in Just Intonation! A veritable "tuning processor" as well, it has many features for constructing, editing, transposing, analyzing and printing Just Scales. Tuning data is shown in Ratios, Cents, Frequencies and Yamaha TU's. Those without a MIDI instrument can hear the Just scales on the computer's built in speaker. Holds 16 scales in memory, which are selected by single keystrokes. Tunings may be transposed into any key with another quick stroke. Requires IBM XT/AT or compatible and, for performance, an MPU-401 or compatible MIDI interface. \$60 from DENNY'S SOUND & LIGHT PO Box 12231 Sarasota, FL 34278.



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A note from the editor:

Here on the back page of each issue of **Experimental Musical Instruments**, we have a listing of articles relating to unusual musical instruments which have appeared recently in other publications. For this current issue, the listing had been particularly extensive, because of the longer-than-usual time since our last issue. HOWEVER, a week before we were to have gone to press, EMI's computer suffered a hard disk crash. (No, it wasn't the fabled Michaelangelo, although by chance it happened near the time the virus was scheduled to strike.) Among the lost data was the file containing the "Recent Articles" listing, which had been composed a couple of days before. When I had recovered my composure enough to begin repairing the damage and trying to make up lost work, I went into the back room to gather up the last few months' magazines, ready to begin sifting through them once again.

They weren't there. In the intervening time, I had taken them to the recycling center. In other words: the magazines have gone to the mill; my disk files have gone to the great void; and there is isn't much of a listing of recent articles on the back of this issue.

But I do save some of the magazines, and included among the saved is the one that I was most eager to report on this time. SO, here are listings for several of the articles from the first issue of the new **Leonardo Music Journal** (Pergamon Press, 395 Saw Mill River Road, Elmsford, NY 10523). See also the commentary on the new publication on page 4 of this issue under "Notes from Here and There".

**"Komposisi Baru: On Contemporary Composition in Indonesia"**, by I Wayan Sadra with Jody Diamond.

This article discusses aspects of contemporary music composition and performance in a part of the world best known in the west for its classical music traditions. Included in the article are several photographs and descriptions of unusual and adventurous musical sound sources.

**"The Airplayer Series: Manipulation of Light, Sound and Space through Technology"**, by Sara Garden Armstrong with Robert Ross.

A report on an ongoing series of sound and sculpture installations by Sara Garden Armstrong. The installations use long tubes running through bizarre sculptural forms, with rushing computer-controlled air sounds and pre-recorded sounds emerging from the tubes.

**"Low Brass: The Evolution of Trombone-Propelled Electronics"**, by Nicolas Collins

Description of Collins' unique approaches to musical instrument control systems. Two types are described: 1) Backward guitars use

electromagnetically-driven electric guitar strings. Signals from various sources including radio and tape recordings are fed into the electromagnetic guitar pickups, causing the metal strings to respond with their own resonances, which are then picked up by contact mics at the bridge. 2) The trombone controller is a control mechanism for electronic sound sources and processors, in the form of an old trombone body wired up for the purpose. The player who appears to be playing a trombone is actually manipulating electronic sounds from external sources.

**"Trends in New Acoustic Musical Instrument Design"**, by Bart Hopkin.

A broad overview of recent activity in creative instrument making. The article also speculates on ways in which those who work with acoustic sound sources tend to approach sound differently from those who work primarily with electronics.

**"Relative Ratio Tuning: An Intonational Strategy for Performance Systems"**, by Martin Bartlett.

Ideas for a more inclusive approach to just intonation made possible by advances in microprocessor music. Bartlett proposes thinking in terms of matrices of pitch relationships built around each possible tone, rather than basing tuning relationships primarily on a single tonic pitch for a given key.

**"Local Conditions and Perceptual Concerns: Notes on Several Sound Works"**, by Ed Osborn.

This article reports on several of Osborn's sound installations and performance works, which sometimes involve playing with concepts and images related to sound as much as they involve actual sound.

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